Clinical Report

Different Stages in Attentional Processing of Facial Expressions of Pain: A Dot-Probe Task Modification

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Abstract: The way in which individuals attend to pain-related stimuli is thought to affect their pain experience. Early and late stages of processing, with shifts from attentional engagement to disengagement (avoidance), have been identified, but rarely investigated in the same protocol. Therefore, the present study aimed to consider 2 time frames that might be indicative of attentional engagement and disengagement. One hundred pain-free individuals performed a modified dot-probe task with pictorial stimuli displaying affective facial expressions (ie, pain, anger, joy, neutral face), presented either for 100 ms or for 500 ms. Because fear of pain has been found to moderate attentional processing of pain stimuli, the Fear of Pain Questionnaire (FPQ III) was also administered. Results indicated both early attentional engagement and later disengagement (avoidance) for negative facial expressions (anger, pain). This pattern was most prominent for pain faces and among those participants high in pain-related fear. Taken together, these findings provide evidence that the dot-probe task is suitable to investigate different stages of attentional processing for pain-related stimuli. In accordance with the vigilance-avoidance hypothesis, pain-related stimuli seem to attract attention quickly, but attentional avoidance may occur shortly after.

Perspective: We focused on different stages of attentional processing of pain faces in pain-free individuals. Results highlight the importance of distinguishing between early (engagement) and later (disengagement) components of attention, as well as considering the role that fear of pain has in understanding the nature of these effects.

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Key words: Attentional bias, fear of pain, facial expressions of pain, dot-probe task.

There is now substantial evidence that biases in attention toward pain-related material may contribute to pain and pain behaviors in both acute and chronic pain conditions. However, the precise nature of this association is still poorly understood and may depend on both the methods of attentional capture and the type of pain being examined. For example, attentional avoidance of pain-related stimuli prior to surgery seems predictive of postoperative pain, whereas enhanced attentional engagement to pain-related stimuli has been reported in chronic pain patients.

In terms of methods, primary task paradigms have most often been used (for a review see). For example, in the dot-probe task, participants are required to make a decision about the location of a dot. Pain-related stimuli precede the appearance of the dot but are not critical for correct responding. However, the presence of such pain-related material seems to be sufficiently salient to be processed and capture attention. In most of these studies, verbal stimuli, like the word “burning,” have been used. However, more recently, studies have applied pictorial stimuli with promising results. Pictures with facial expression of pain are potentially suitable because individuals universally attend to facial expressions of emotions, whereas reading words requires learned abilities. Furthermore, viewing facial expressions of pain elicits strong brain...
activation in areas that are also activated during the experience of true pain.\textsuperscript{6,8,40}

Alongside the choice of stimulus material, a second methodological issue relates to the presentation time of pain-related material that is used in dot-probe tasks. This is important as it is assumed that different presentation times may reflect different stages of attentional processing. Engagement is assumed to occur early in the attentional processing of affective stimuli, whereas disengagement processes rather reflect attempts to cope at a later stage.\textsuperscript{25,26} For example, difficulties in disengaging are thought to be reflected in studies that present pain-related stimuli for relatively longer durations (eg, 1,250 ms),\textsuperscript{37,38} whereas initial engagement is thought to be reflected when exposure duration is limited (eg, 100 ms).\textsuperscript{41} For stimuli presented at the more typical 500 ms, both modes of attentional processing have been observed (eg, disengagement,\textsuperscript{11,26} engagement\textsuperscript{37,38}). The problem here is that it is unclear exactly when the engagement phase ends and disengagement begins.\textsuperscript{37} For example, in a pain-free sample, Koster et al\textsuperscript{26} found strong attentional engagement with threatening pictures presented for 100 ms but attentional avoidance as soon as these pictures were presented for 500 ms.

Because both attentional engagement with and avoidance of pain-related material might be differentially related to pain and pain behavior, ascertaining separate parameters for these 2 biases—eg, congruency and incongruency indices—is proposed to be advantageous.\textsuperscript{25} Thus, in the present study, different presentation times and different parameters were used to reflect early and later stages of attention processing: initial engagement at 100 ms and later disengagement at 500 ms.

As regards the temporal appearance of biases, we assumed that confrontation with pain-related material produces a vigilance-avoidant pattern of attention, which has already been described for fear-related stimuli\textsuperscript{42}: enhanced early attentional engagement succeeded by strong attentional avoidance. Such a differentiation of consecutive phases has not yet been considered in studies on the pain-attention bias. Given that fear of pain has been shown to moderate the effects of fear-related biases,\textsuperscript{2,15,23} such a pattern was thought to be most pronounced in highly pain-fearful participants.

### Methods

#### Participants

One hundred healthy Caucasian individuals (50 women) ranging in age from 18 to 65 years (M = 39.7, SD = 13.4) participated in the present study. Participants were recruited via announcement in local newspapers in Bamberg and among students of the Otto-Friedrich University of Bamberg. Sex of individuals was equally distributed in each age range (18–29, 30–39, 40–49, and 50–65 years), and no significant sex differences in age were found (males: M = 39.8 years, SD = 13.4; females: M = 39.6 years, SD = 13.0; t(98) = .08, P = .935). All participants were without history of any psychiatric or neurological disorders. None of the individuals studied were under psychopharmacological treatment, took analgesics, or reported any acute or chronic pain conditions or previous major surgical intervention.

The study protocol was approved by the ethics committee of the Otto-Friedrich University of Bamberg. All participants gave written informed consent. Except for students, who received course credit as compensation for their efforts, all individuals were paid for participation.

#### Procedures

The session took place between 9.00 a.m. and 6.00 p.m. and lasted for approximately 1 hour. After performing the computerized dot-probe task, participants filled out the Fear of Pain Questionnaire (FPQ III\textsuperscript{32}).

#### Measures

### Assessment of Attentional Processing of Affective Pictures: Dot-Probe Task

A selective attention task for affective stimuli based on the dot-probe task was used with monochrome photographs of affective facial expressions (pain, anger, joy, neutral face) extracted from the Montreal Pain and Affective Face Clips (MPAFC)\textsuperscript{39} as stimulus material. There were 24 pictures per category. The affective pictures were always paired with pictures displaying neutral faces. Additionally, neutral-neutral picture pairs served as control items (see Fig 1).

First, a fixation cross was presented for 500 ms in the center of a computer screen. Next, 2 pictures (either a neutral picture paired with an affective picture, or 2 neutral pictures) were presented concurrently, left and right to the central fixation point. Each pair of pictures was presented twice, once at each of the 2 presentation times: 100 and 500 ms (see Fig 1). The 2 different presentation times were included as they are thought to capture different stages of processing.\textsuperscript{25} The orders of presentation times, affective picture categories, and sides of appearance of the affective picture at the screen were randomized once, and then applied in the same order for all participants. The result of the randomization protocols was checked as regards the frequency of the 3 orders—to be controlled—over the test; there were no significant frequency differences in presentation times, affective picture categories, and sides of appearance between test phases (trials arranged in quartiles), which suggests that order effects could be minimized.

Immediately after the concurrent presentation of the 2 pictures, a dot appeared in the same position as 1 of the 2 pictures (see Fig 1A). The participants were instructed to indicate as quickly as possible the side the dot had appeared using a response box.

In the present study, we used a 3-button response panel.\textsuperscript{5,22} The centrally positioned button served as a holding button, and the 2 dot location buttons (slightly above and either to the right or to the left of the holding button) were used to indicate dot probe location (side of appearance at the screen). In each
trial, the starting position of the index finger was on the central holding button. This procedure reduces unwanted error variance because the movement distances between the buttons were made equal for all participants. Participants were instructed to release the holding button only to respond to the appearance of the dot. This approach allowed for a decomposition of reaction time (ie, time to evaluate a stimulus and select a response) from movement time (ie, time to execute a motor response).

Figure 1. (A) Design of trials in the dot-probe task. Affective pictures display anger, pain or joy faces; pictures taken from the MPAFC.39 (B) Schematic illustration of definition of congruency and incongruency for calculation of the corresponding bias indices (CI, ICI) in the dot-probe task. Neutral conditions were used as reference for the congruent and incongruent conditions; pictures were taken from the MPAFC.39
The 3-button response panel was thought to be a methodological improvement because previous research has identified age as having an important influence on movement time but not on reaction time. The 3-button panel therefore allowed us to better control for motor slowing in our study sample, with a wide age range (i.e., 18–65 years). In our version of the dot-probe task, reaction time was taken from the time interval between appearance of the dot and the release of the holding button (once a decision had been made). The time interval between releasing the holding button and pressing 1 of the 2 location response buttons was taken as movement time. Reaction time proved to be predominantly influenced by the cognitive task demands and was therefore assumed to reflect attentional factors. Thus, in the present study we focused on the reaction time, as motor processes were not our major interest.

After 10 practice trials, participants had to complete 192 test trials (24 trials per each affective category, twice for the 2 presentation times).

To capture the expected vigilant-avoidant pattern with early attentional engagement and succeeding disengagement, 2 different bias indices were calculated based on the reaction times following the formula suggested by Asmundson et al; these were the congruency index (CI100) for picture-pairs presented at 100 ms (CI = [(neutral-neutral trials/4) – (congruent neutral-affective trials/2)]) and the incongruency index (ICI500) for picture-pairs presented at 500 ms (ICI = [(incongruent neutral-affective trials/2) – (neutral-neutral trials/4)]) (see also Fig 1B). In addition, the CI for picture-pairs presented for 500 ms (CI500) was calculated, because it is still unclear whether engagement has already ended and disengagement prevails at 500 ms. Thus, the CI500 was computed to control for the theoretical alternative that attentional engagement persists at 500 ms.

For the sake of completeness, one might have wished to have computed the ICI for 100 ms trials as well. However, we thought this was not suitable conceptually because 1) disengagement cannot start that briefly after stimulus onset given that prior to this a phase of attentional engagement is necessary; and 2) possibly due to 1), there was an unacceptably large range in ICI100 scores for a meaningful analysis to be conducted (i.e., up to 41% larger compared to the other indices). Therefore, the ICI100 was not included here.

The combinations of the CI100 with the short presentation time (100 ms) and the ICI500 with the long presentation time (500 ms) were thought to reflect best the dynamics of early engagement with and later disengagement from affective material. A positive score on the CI (CI100, CI500) reflects attentional engagement with the affective stimuli (e.g., facial display of joy, anger, or pain). Difficulty in disengaging from the affective stimuli is indicated by a positive score on the ICI500; a negative score in this bias parameter represents strong attentional disengagement or avoidance of the affective picture.

Not considering these newly introduced bias indices, previous research with the dot-probe task has predominantly used the classical attentional bias index calculated by the subtraction of the congruent affective-neutral trials from the incongruent affective-neutral trials. To ease the comparability of our study with others making use of the dot-probe task in pain research, detailed information about the classical attentional bias index are offered in Appendix A.

FPQ III

The FPQ III was developed as a comprehensive measure of fear of pain and validated in a pain-free population as well as in chronic back pain patients. Participants are instructed to rate the degree of fear they would likely experience if confronted with a variety of potentially painful situations. The FPQ III contains 30 items that can be divided into 3 subscales regarding the fear of 3 types of pain: severe pain (“breaking an arm”), minor pain (“paper cut on the finger”), and medical pain (“receiving an injection in the mouth”). The items are rated on a 5-point scale. For developing a German version, the FPQ III was submitted to a forward-backward procedure of translation, which means that the German translation was in turn the starting point for a translation by an English native speaker (with German as his second language) back to English. Translation to German was improved until the original English version and the final English version were sufficiently similar. The German FPQ III demonstrated good internal consistency (Cronbach’s α = .90), which was in accordance with Cronbach’s α = .92 reported for the English version. For further analyses, we used the combined sum score of the FPQ III.

Structured Interview

The Structured Clinical Interview for DSM Disorders (SCID interview) was used as an initial screening to exclude participants who suffered from psychiatric disorders. The SCID is a structured interview according to Diagnostic and Statistical Manual of Mental Disorders-IV. Based on the structured interview, 1 individual was excluded from the study (schizophrenic disorder: F20.3).

Statistics

For descriptive statistics, mean and standard deviations are given.

Because for bias parameters (CI100, CI500, ICI500) a score of zero means that affective facial displays are not differently processed than neutral facial displays, bias can only be assumed if parameters deviate substantially from zero. Therefore, 1-sample t-tests on significant deviations from zero were performed.

After having investigated the existence of attentional biases, analyses of variance (ANOVAs) for repeated measures were performed to look for differences in biases between the 3 affective picture categories; namely, joy, anger, and pain. Since our focus was predominantly on the main effect “emotion” but not on any interaction effect, 3 ANOVAs were conducted (i.e., for all bias indices). Additionally, an analysis of covariance (ANCOVA) was conducted, with fear of pain as a covariate, to investigate if potential differences between affective categories in bias indices are due to the level of fear. In case of violation of
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sphericity, values of Greenhouse-Geisser correction were reported.

For all analyses in the present study, results were reported as significant if reaching a minimum alpha level of \( \leq .05 \). In case of directed hypotheses, 1-tailed tests were run and indicated as such in the text. Directed hypotheses are available as regards 1) the occurrence of a vigilance-avoidance pattern of attentional processing of negative stimuli (positive CI100 – negative ICI500); and 2) the more pronounced effects in pain-fearful individuals. In all other cases, 2-tailed tests were run. Differences between conditions were also described by computation of Cohen’s d.

Results

Existence of Attentional Biases

First, t-tests for deviation from zero were conducted for the entire sample for all affective picture category indices (ie, anger, joy, pain). Significant results would suggest substantially biased attentional processing of affective compared to neutral pictures.

Results showed a significant deviation from zero for the CI100 \( t(99) = 2.16, P = .017 \), Cohen’s d = .22, 1-tailed) and the ICI500 \( t(99) = -2.39, P = .001 \), Cohen’s d = .24, 1-tailed) participants strongly engaged with briefly presented pain faces (100 ms) and disengaged attention from the same stimuli when presented at 500 ms.

Bias indices for faces showing joy and anger, respectively, were not found to deviate significantly from zero (joy: CI100 \( t(99) = -.63, P = .529 \), Cohen’s d = .06; ICI500 \( t(99) = 1.00, P = .322 \), Cohen’s d = .10; anger: CI100 \( t(99) = 1.32, P = .096 \), Cohen’s d = .13, 1-tailed; ICI500 \( t(99) = -.25, P = .108 \), Cohen’s d = .13, 1-tailed). Means and standard deviations of reaction times and bias indices are presented in Table 1.

Conducting t-tests for deviation from zero for CI500 did not lead to any significant result: joy \( t(99) = 1.87, P = .068 \), Cohen’s d = .08; anger \( t(99) = -1.03, P = .307 \), Cohen’s d = .14; pain \( t(99) = 2.12, P = .038 \), Cohen’s d = .80; neutral \( t(99) = 1.77, P = .098 \), Cohen’s d = .30.

Differences of Attentional Biases Between Affective Categories

For assessing differences in attentional engagement (CI100, ICI500) and disengagement (ICI500) between affective picture categories (factor emotion: joy, anger, pain), separate ANOVAs for the 3 bias indices were performed.

A significant main effect for emotion was found for both CI100 (F(2, 198) = 3.47, \( P = .033 \), partial \( \eta^2 = .03 \)) and ICI500 (F(2, 198) = 4.36, \( P = .014 \), partial \( \eta^2 = .04 \)) whereas no such main effect for emotion was observed for CI500 (F(2, 198) = 2.21, \( P = .112 \), partial \( \eta^2 = .02 \)).

Post hoc pairwise comparisons showed that CI100 was significantly increased for pictures displaying pain faces \( t(99) = 6.24, P = .006 \), Cohen’s d = 1.21, 1-tailed) and anger faces \( t(99) = -4.47, P = .025 \), Cohen’s d = .80, 1-tailed) compared to facial expressions of joy, whereas the CI500 computed for the facial display of pain and anger did not differ significantly from each other \( t(99) = -1.77, P = .098 \), Cohen’s d = .20 (see Table 1).

Post hoc pairwise comparisons for ICI500 showed a significant difference between facial display of pain and joy \( t(99) = 8.68, P = .004 \), Cohen’s d = 1.61, 1-tailed) as well as a significant difference between facial display of anger and joy \( t(99) = 4.99, P = .003 \), Cohen’s d = .80, 1-tailed); were scores were significantly lower for pain and anger faces, respectively (see Table 1). Accordingly, individuals strongly disengaged from facial display of pain and anger compared to faces displaying joy. No significant differences were observed between anger and pain faces \( t(99) = 3.68, P = .211 \), Cohen’s d = .60.

In the present study the 3-button response panel allowed for assessing reaction time and movement time separately; reaction time was used to calculate the bias indices and to test our hypotheses, because this measure has been proven to be sensitive to cognitive influences (see also Measures). Nevertheless, we repeated our

Table 1. Means (M) and Standard Deviations (SD) of Dot-Probe Response Latencies and Bias Indices for the Entire Sample and Low and High FPQ III Subsamples

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Presentation Time*</th>
<th>Congruent Trial</th>
<th>Incongruent Trial</th>
<th>Bias Index</th>
<th>N = 100</th>
<th>Low FPQ III</th>
<th>High FPQ III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anger</td>
<td>100</td>
<td>389.95 (60.48)</td>
<td>407.14 (56.12)</td>
<td>CI100</td>
<td>3.06</td>
<td>1.45</td>
<td>4.67</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>387.02 (64.48)</td>
<td>381.21 (60.02)</td>
<td>ICI500</td>
<td>-2.80</td>
<td>-6.11</td>
<td>-4.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CI500</td>
<td>-3.02</td>
<td>-2.12</td>
<td>-3.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CI100</td>
<td>-1.41</td>
<td>-2.92</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CI500</td>
<td>-1.77</td>
<td>-5.37</td>
<td>-7.59</td>
</tr>
<tr>
<td>Joy</td>
<td>100</td>
<td>394.42 (59.33)</td>
<td>391.76 (56.35)</td>
<td>CI100</td>
<td>2.20</td>
<td>1.39</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>387.10 (60.73)</td>
<td>386.20 (62.75)</td>
<td>ICI500</td>
<td>-3.09</td>
<td>-4.86</td>
<td>-1.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CI500</td>
<td>-4.82</td>
<td>3.20</td>
<td>6.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CI500</td>
<td>-6.48</td>
<td>-5.37</td>
<td>-7.59</td>
</tr>
<tr>
<td>Pain</td>
<td>100</td>
<td>385.18 (57.28)</td>
<td>393.59 (60.91)</td>
<td>CI100</td>
<td>2.29</td>
<td>.86</td>
<td>3.71</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>381.72 (61.77)</td>
<td>377.53 (58.39)</td>
<td>ICI500</td>
<td>2.59</td>
<td>.82</td>
<td>3.71</td>
</tr>
<tr>
<td>Neutral</td>
<td>100</td>
<td>393.01 (56.37)</td>
<td>384.00 (62.72)</td>
<td>CI500</td>
<td>2.29</td>
<td>.86</td>
<td>3.71</td>
</tr>
</tbody>
</table>

*Time in milliseconds.
|Congruent; the dot replaced the emotional face.
|Incongruent; the dot replaced the neutral face.

...
analyses of bias indices by using instead movement time to verify our original decision. According to our expectations, all analyses failed to reach the requested significance level. The exact statistics are provided in Appendix B.

Effect of Fear of Pain on Attentional Biases

Since fear of pain was assumed to be a variable directing attentional processing of pain-related stimuli, the sum score of the FPQ III was included as a covariate (ANCOVA) into analysis of variance. Results showed that the significant main effects of emotion for both CI100 and ICI500 in the ANOVAs were no longer significant after inclusion of FPQ III as covariate (see Table 2 for the exact statistics). This suggests an effect of fear of pain on the 2 bias indices. However, it is also known that the inclusion of additional variables changes the degrees of freedom, which in turn might change previously significant results into nonsignificant ones and serve as alternative statistical explanation.

For detailed illustration of the potential interaction between fear of pain and attentional biases, individuals with low (FPQ III: M = 54.28, SD = 8.87, n = 50) and high (FPQ III: M = 80.44, SD = 10.09, n = 50) fear of pain levels were determined by median split. The 2 groups did not differ in age (t(98) = .92, P = .365, Cohen’s d = .13); the same was true for participants with high fear of pain levels exhibited attentional biases taking the form of strong attentional engagement toward the facial display of pain at 100 ms and of enhanced avoidance of the facial display of pain at 500 ms (see Fig 2).

Table 2. ANCOVAs for CI100, ICI500, and CI500 With FPQ III Included as Covariate

<table>
<thead>
<tr>
<th>Bias</th>
<th>Effect</th>
<th>Statistic</th>
<th>Partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI100</td>
<td>Emotion</td>
<td>F(2,196) = .61, P = .454, partial η² = .01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>fear of pain</td>
<td>F(2,196) = .49, P = .661, partial η² = .01</td>
<td>0.01</td>
</tr>
<tr>
<td>ICI500</td>
<td>Emotion</td>
<td>F(2,196) = .01, P = .993, partial η² = .00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>fear of pain</td>
<td>F(2,196) = .26, P = .769, partial η² = .00</td>
<td>0.00</td>
</tr>
<tr>
<td>CI500</td>
<td>Emotion</td>
<td>F(2,196) = .05, P = .955, partial η² = .00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>fear of pain</td>
<td>F(2,196) = .06, P = .947, partial η² = .00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 2. Mean of congruency and incongruency indices (bias measures for attentional engagement (CI) with and disengagement (ICI) from pictures of faces displaying pain, anger, and joy, respectively) in individuals with high and low levels of fear of pain. Subgroups are based on median split of FPQ III (both n = 50); SD of bias indices are presented in Table 1.

No significant deviation from zero was found in the high FPQ III subgroup for faces showing joy (CI100: t(49) = .03, P = .974, Cohen’s d = .01; ICI500: t(49) = .90, P = .370, Cohen’s d = .13) and anger (CI100: t(49) = 1.32, P = .192, Cohen’s d = .19; ICI500: t(49) = −1.48, P = .145, Cohen’s d = .21). The same was true for participants with low fear of pain, as regards joy (CI100: t(49) = −.92, P = .365, Cohen’s d = .13; ICI500: t(49) = .47, P = .638, Cohen’s d = .07) and anger (CI100: t(49) = .48, P = .635, Cohen’s d = .07; ICI500: t(49) = −.21, P = .838, Cohen’s d = .03).

The same analysis was repeated for CI500 to determine effects of affective pictures on attentional engagement at 500 ms, which were dependent on the individual level of pain-related fear. However, no significant main or interaction effects were found in the ANCOVA (see Table 2).

Discussion

The first objective of the present study was to investigate different stages of attentional processing of affective facial displays, in particular displays of pain, anger and joy, in a primary task paradigm. For that purpose, a modified dot-probe task including 2 different presentation times was designed to allow investigating biases...
for both attentional engagement and disengagement. As a second objective, individual factors relating in particular to the processing of pain were assessed in their influence on the dot-probe task performance by studying the impact of low and high levels of fear of pain.

**Attentional Engagement With and Disengagement From the Facial Displays of Pain, Anger, and Joy**

Significant attentional biases were observed only for pain faces but not for faces displaying anger or joy. The existence of attentional bias was defined as significant deviation from a score of zero, which results only when concurrent presentation of affective and neutral facial displays in the dot-probe task does not produce any differences in reaction time for the 2 alternatives. Here, biases took the form of attentional engagement when faces were presented for 100 ms and attentional disengagement (avoidance) when faces were presented for 500 ms. We use the term attentional avoidance to highlight the fact that attention appeared to shift away from the negative stimuli. However, it should be noted that such attentional avoidance is assumed to have occurred after an initial phase of confrontation with the negative stimuli and thus should not be mistaken for attentional strategies, which completely block the processing of negative stimuli.

The interpretation presented so far suggests that the existence of substantial attentional biases is limited to trials with pain-related material, ie, pain faces. Direct comparisons of the biases associated with the different affective categories provided partial support of this assumption. Participants’ engagement was significantly stronger for both pain and anger faces presented at 100 ms than for joy faces. Likewise, at the later stage of 500 ms, attentional avoidance was found to be significantly stronger for the 2 negative facial displays compared to joy faces. Thus, faces with negative facial displays produced an attentional pattern characterized first by engagement and later by avoidance, which was most pronounced for pain faces.

Pictorial stimuli presented for 500 ms may also reflect continued attentional engagement instead of starting disengagement (avoidance). For discrimination between these 2 alternatives, we additionally calculated an engagement index for stimuli presented for 500 ms (CI500). Since the CI500 failed to produce any significant results as regards both the existence of an attentional bias and its variation by the affective content of the pictures, our findings suggest the predominance of disengagement from facial expressions of negative emotions and pain at 500 ms, at least in pain-free individuals.

Our findings are certainly noteworthy because substantial attentional biases toward pain-related stimuli have not always been identified in pain-free individuals when using the dot-probe task. It is possible that our choice of facial stimuli with known sufficient affective impact may have been critical, especially in individuals with no psychological conditions known to bias attention. As suggested by our data, already moderately increased levels of fear of pain strengthen the tendency to first favor and later avoid pain-related information. Accordingly, our stimulus material appeared to be a good compromise between high sensitivity for the detection of small attentional biases and enough range for changes when investigating individuals with substantial biases.

Our finding of an attentional engagement-avoidance pattern for pain-related stimuli is consistent with previous results from Koster et al. Using a dot-probe task, they found that highly threatening (but not strictly pain-related, as in our study) pictures elicited strong attentional engagement when presented for 100 ms whereas attentional avoidance was observed at presentation times of 500 ms. In addition, our finding of pain faces being attentionally avoided at 500 ms is consistent with data reported by Khatibi et al from a pain-free control sample.

This attentional pattern, with first engagement and later disengagement, which might be specific for threat-related stimuli, is consistent with the vigilance-avoidance hypothesis. For example, Martin et al argue that attention tends to engage early with stimuli comprising natural danger or threat signals, allowing for more detailed processing of these cues. On the other hand, attentional avoidance of threat or of negative stimuli may reflect an attempt to regulate mood, ie, to minimize discomfort by cognitively avoiding such aversive stimuli. In our study, this vigilance-avoidance pattern of attention was corroborated by use of the dot-probe task, where it is assumed that automatic processing of the pain-related stimuli is sufficient to execute the task successfully. Thus, it is less likely that this attentional engagement-avoidance pattern is due to controlled processes.

**Effect of Fear of Pain on Attentional Biases**

There is converging evidence that habitually fearful individuals show altered attentional processing when confronted with their feared stimuli. Such alterations are supposed to be learned and to result in stable action schemes, which are activated easily by affective cues and thereafter reliably influence stimulus processing. This was reason enough for us to assume that attentional biases toward pain-related stimuli are particularly strong in individuals with heightened fear of pain.

In fact, participants who reported heightened fear of pain showed the pattern of attentional engagement-avoidance regarding pain faces—described already for the whole sample—in an especially pronounced fashion. In contrast, in the subsample of individuals classified as having low levels of fear of pain, no substantial attentional biases could be detected.

Such hypervigilance-attentional avoidance pattern has been assumed to be related to the development and maintenance of anxiety disorders. Therefore, heightened anxiety may be not only the cause of altered attention but also its consequence. If similar relationships hold also for the etiology of pain, attentional biases could be considered predisposing factors for the development and chronification.
of postoperative pain outcomes.\textsuperscript{27,29} Furthermore, attentional avoidance was found to be a prominent predictor of postoperative pain outcomes.\textsuperscript{27,29}

Accordingly, the 2 phases in the vigilant-avoidant pattern of attention, in terms of first a very brief confrontation with pain-related information followed by attentional avoidance, might be of different relevance in the course of development of pain. Pain-prone persons may start with avoiding useful pain-related information but would do better when elaborating on pain information in order to prepare successful pain coping. Later in the course of chronification, these pain-prone individuals may become preoccupied by pain-related stimuli and present at this time as mainly attentionally engaged with pain.\textsuperscript{30} These speculations on the changing relevance of attentional factors in the course of pain chronification may appear plausible but require empirical verification. In contrast, in individuals without such a proneness to pain, the vigilance-attentional avoidance pattern might be adaptive by both preventing harm to the organism through attentional engagement and preventing fear through subsequent attentional avoidance.

Limitations

The attentional bias toward pain-related stimuli found here required a sizeable number of participants (N = 100) for verification. A marginally higher number of participants might have produced similar effects for the facial display of anger. At least, the present study cannot be called “underpowered” in comparison with other studies of this kind.

The selection of the 2 presentation times for the affective pictures (100 ms, 500 ms) to target early and late phases of processing in the dot-probe task was guided by the literature but could be considered somewhat arbitrary. Whether a presentation time of 500 ms captures attentional engagement or disengagement is still open to discussion. Therefore, we tried to answer this question by calculating both engagement and disengagement indices for 500 ms. Our data favor the assumption of already prevailing disengagement at 500 ms. However, the additional use of presentations times beyond the range applied in the present study (eg, 1,250 ms\textsuperscript{30,37}) would definitely improve the understanding of the time-course of attentional processing and should therefore be considered for future studies on the dot-probe task. The advantage of using more than 2 presentation times might be counterbalanced by an increased number of necessary trials, which would in turn result in long test durations and, by that, in a decline of sustained attention over the test period.

A confound with attentional bias as assessed in the dot-probe task might result from behavioral freezing, which might be triggered by threatening stimuli and might in turn influence reaction times.\textsuperscript{10} However, reaction times were not slower in trials including pain or anger faces, both for the entire sample and for pain-fearful individuals in the present study. In contrast, all individuals showed faster reaction times for pain and anger faces. Accordingly, behavioral freezing did not occur.

Finally, it should be mentioned that the order of FPQ III and dot-probe task was not counterbalanced. We decided to conduct the FPQ III after the dot-probe task to minimize the potential influence of elaborating on items with the focus on fear and pain on attentional processing in the dot-probe task.

In sum, the use of a modified version of the dot-probe task allowed for observing an early attentional engagement with threat-related stimuli followed by attentional avoidance of the same stimuli, which was most pronounced for pain faces. Especially in individuals with high levels of fear of pain, the attentional engagement-avoidance pattern was distinct and definite for pain faces. The present results highlight again the importance of examining different stages of attentional processing of pain-related stimuli and to distinguish between different components such as attentional engagement and disengagement in order to introduce the attentional biases at these stages as useful predictors for and as covariates of clinical pain problems.

References


Appendix A. Traditional Bias Indices (M, SD) for the Entire Sample (N = 100) and the Subsamples With low and High Fear of Pain Derived From Median-Split on the FPQ III (Both n = 50)

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Emotion</th>
<th>N = 100</th>
<th>Low FPQ III</th>
<th>High FPQ III</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Joy</td>
<td>-2.65 (24.46)</td>
<td>-3.51 (28.01)</td>
<td>-1.80 (20.55)</td>
</tr>
<tr>
<td></td>
<td>Anger</td>
<td>17.19 (34.03)</td>
<td>19.38 (34.74)</td>
<td>15.00 (33.51)</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>5.42 (25.99)</td>
<td>11.77 (29.79)</td>
<td>-.94 (19.86)</td>
</tr>
<tr>
<td>500</td>
<td>Joy</td>
<td>-.89 (29.51)</td>
<td>-3.47 (31.55)</td>
<td>1.68 (27.39)</td>
</tr>
<tr>
<td></td>
<td>Anger</td>
<td>-5.81 (25.96)</td>
<td>-2.73 (29.00)</td>
<td>-8.89 (22.40)</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>-4.19 (27.72)</td>
<td>-4.51 (29.67)</td>
<td>-3.88 (25.93)</td>
</tr>
</tbody>
</table>
### Appendix B. Inference Statistics for Movement Time (MT)

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Bias</th>
<th>M (SD)</th>
<th>Test Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joy</td>
<td>CI MT100</td>
<td>-4.23 (27.54)</td>
<td>t(99) = -1.54, P = .128</td>
</tr>
<tr>
<td></td>
<td>CI MT500</td>
<td>.91 (26.67)</td>
<td>t(99) = .34, P = .733</td>
</tr>
<tr>
<td>Anger</td>
<td>CI MT100</td>
<td>1.83 (22.83)</td>
<td>t(99) = .80, P = .425</td>
</tr>
<tr>
<td></td>
<td>CI MT500</td>
<td>2.49 (29.64)</td>
<td>t(99) = .84, P = .403</td>
</tr>
<tr>
<td>Pain</td>
<td>CI MT100</td>
<td>-4.65 (30.10)</td>
<td>t(99) = -1.55, P = .125</td>
</tr>
<tr>
<td></td>
<td>CI MT500</td>
<td>1.19 (27.38)</td>
<td>t(99) = .43, P = .665</td>
</tr>
</tbody>
</table>

2. ANOVA (factor emotion)
- Main effect emotion
  - CI MT100: F(2,198) = 2.59, P = .078
  - CI MT500: F(2,198) = .74, P = .478